## A RING-SPINNING SYSTEM FOR MAKING YARN HAVING A MAGNETICALLY-ELEVATED RING

### TECHNICAL FIELD OF THE INVENTION

[0001]   The present invention is related to manufacturing yarn from fiber strands and, more particularly, to a ring-spinning system for manufacturing yarn that employs a magnetically-elevated ring.

### BACKGROUND OF THE INVENTION

[0002]   Spinning is the process of forming yarns from fiber strands. The existing spinning systems may be divided into two main categories, namely, continuous spinning systems and non-continuous spinning systems. In continuous spinning, the fiber strand fed to the spinning system follows a continuous path throughout the entire spinning process from the feeding point to the yarn package. Ring spinning and compact spinning are two examples of continuous spinning systems. Continuous spinning systems generally produce high-quality yarn, and a wide diversity of yarn styles, but suffer from a low productivity rate. On the other hand, non-continuous spinning systems generally have high production rates, but produce relatively low-quality yarn.

[0003]   The main factor that limits the production rate of ring-spinning systems is the friction between the traveler and the ring. This friction generates heat sufficient to burn the traveler if its speed is increased over a certain limit. Therefore, either the speed of the system must be kept below a certain limit to prevent damage to the traveler and/or the traveler will be damaged and will have to be replaced frequently. Various attempts have been made to reduce the friction between the traveler and the ring. For example, U.S. Patent Nos. 2,932,152 and 3,851,448 disclose ring-spinning systems wherein the ring is supported in space by either magnetic force or air pressure to prevent the ring from contacting the stationary parts of the system.

[0004]   These two systems use air pressure to stabilize the ring in the transverse direction in addition to the magnetic repulsion force. Simultaneously using two different types of stabilizing forces to stabilize the ring complicates the ring-spinning system and makes the system unsuitable for industrial

applications because the stabilizing forces tend to be difficult to control. Moreover, the absence of a control system makes such systems uncontrollable in the case of start-up operation and in the case of yarn breakage. In addition, the power required by such systems to provide the necessary air pressure and magnetic forces renders them unsuitable for industrial application because they are economically inefficient.

[0005]   A need exists for a ring-spinning system in which the speed and productivity limitations imposed by the traveler are eliminated. A need also exists for a ring-spinning system that utilizes a suspended ring and that has the ability of stabilizing the suspended ring with a high degree of precision. A need also exists for a ring-spinning system that is capable of producing high quality yarn at a high rate of production, and that is economical in terms of power consumption.

## SUMMARY OF THE INVENTION

[0006]   The present invention provides a ring-spinning system characterized in part by the replacement of the ring traveler configuration with only one rotating, floating ring that has an eye on its inner middle surface. This rotating, floating ring with the eye thereon performs the functions previously performed by the ring traveler configuration of twisting the fibers into yarn. The ring is kept suspended in space by the magnetic levitation system of the present invention.

[0007]   In accordance with the preferred embodiment of the present invention, a floating ring is levitated by a well-controlled magnetic field generated by two sets of electromagnetic coils and a set of cylindrical rare earth permanent magnets. The floating ring is rotated around its center by the effect of winding the formed yarns over a rotating spindle at the center of the ring. Sensors and a feedback system are used to control the magnetic fields produced by the electromagnetic coils to maintain the ring in its central position. The sensors preferably are inductive sensors that detect the displacement of the floating ring off its center axis and send information to a controller of the feedback system. The controller outputs signals in response to the received information that cause the magnetic force generated by the coils to be adjusted, which causes the ring to be restored to its central position.

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[0008]   These and other features and advantages of the present invention will become apparent from the following description, drawings and claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0009]   FIG. 1 is an exploded view of the complete mechanical assembly of the present invention.

[0010]   FIG. 2 is a detailed drawing of the stator assembly

[0011]   FIG. 3 is a sectional view of the complete assembly

[0012]   FIG. 4 is detailed drawing of the floating ring

[0013]   FIG. 5 is a detailed drawing of the stator body

[0014]   FIG. 6 is a detailed drawing of the flux plates

[0015]   FIG. 7a and 7b is a detailed drawing of the return flux plates (outer and inner).

[0016]   FIG. 8 is a detailed drawing of the support disk in the Z direction.

[0017]   FIG. 9 is a floating ring touchdown spacer to keep a minimum air gap distance of .25 mm between the floating ring and the flux plates.

[0018]   FIG. 10 is a counter spacer of the floating ring touchdown spacer.

[0019]   FIG. 11 is a finite element mesh of the complete invention.

[0020]   FIG. 12 is a chart of the restoring force versus the current applied to the 4 X-Coils at 0.25, 0.5 and 0.75 mm gap between the floating ring and the flux plates in the X direction.

[0021]   FIG. 13 is a chart of the restoring force in the Z direction versus the displacement of the floating ring in the Z direction and concentric with the stator body.

[0022]   FIG. 14 block diagram of the control system of the present invention

## DETAILED DESCRIPTION OF THE PREFERRED
## EMBODIMENTS OF THE INVENTION

[0023]   In accordance with the present invention, a magnetic ring-spinning device is provided that is capable of supporting a rotating ring in a stable manner around its center without touching the stator part. A rotating spinning ring has an eye that performs the functions equivalent to those performed by the traveler in a conventional ring-spinning system. The ring having the eye will

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be referred to herein as the "floating ring". This floating ring 3 preferably has a form of a short cylinder with two flanges at its ends. The floating ring may be made from many materials, but preferably is made of a silicon steel material in accordance with the preferred embodiment of the present invention.

[0024]    The components of the ring-spinning system in accordance with the preferred embodiment are shown in Fig. 1. The system comprises a stator 1 that has axial holes formed therein for receiving the cylindrical-shaped rare earth permanent magnets 2. The stator 1 also preferably has two radially-extending holes 1b (Fig. 2) for accommodating two respective displacement sensors 20 (Fig. 2), which preferably are of the inductive type. The stator body 1 in accordance with the preferred embodiment is shown in Fig. 5.

[0025]    Two sets of flux plates 4 provide return flux paths for the system. The design of one of the flux plates 4 is shown in Fig. 6. The system is symmetric with respect to its components. The left side of the system in Fig. 1 is shown assembled whereas the right side is shown disassembled. Therefore, only the disassembled components will be described. Each flux plate 4 preferably has five blind holes on one side and one blind hole on the other side. The five holes are made for insertion of the ends of the permanent magnets 2 and the other hole is made for insertion of the end of the electromagnet core. These plates 4 preferably are made of silicon steel material. Eight electromagnet coils 11 are included in the system. Only four of the coils 11 are shown in the disassembled portion of Fig. 1. The coils 11 preferably have silicon steel cylindrical cores. These coils 11 are arranged in two sets. One set is located on one side of the stator and the other set on the other side in symmetrical way.

[0026]    Two sets of return flux path plates 12 and 13 are incorporated into the system. Each set includes two separate semicircular pieces. Each piece connects two coils from one side of the system, which will be referred to hereinafter as X-coils or Y-coils. These return flux path plates 12 and 13 preferably are made of silicon steel material. The preferred design of the flux plates is shown in FIGS. 7A and 7B. A passive supporting bearing subassembly 7, 8, 10 and 14 (FIG. 1) provides support for the axial positioning of the rotating floating ring 3. This subassembly includes two annular disks having annular grooves where

ring permanent magnets are installed. One of the annular disks 14 is mounted on the floating ring 3 and has a groove formed in it in which one of the ring permanent magnets 11 is installed. The other annular disk in which the other ring permanent magnet 8 is installed is mounted on stationary support part 7. The stationary support part in accordance with the preferred embodiment is shown in Fig. 8. The preferred designs for the floating ring spacer 6 and the stator spacer 5 are shown in FIGS. 9 and 10, respectively.

[0027] The ring permanent magnets 8 and 11 are arranged to operate in a repulsive mode. This arrangement is capable of supporting the rotating ring 3 in the axial direction during rotation. Fig. 4 illustrates the design of the floating ring 3 in accordance with the preferred embodiment. The ring-spinning system device is assembled together by eight non-ferrous material bolts. FIG. 3 shows the principal of operation of the system of the present invention. The permanent magnets 2 (FIG. 1), which are arranged on the stator body 1 (FIG. 1) uniformly, are used to generate a fixed magnetic field capable of supporting the floating ring 3 (FIG. 1) in the Z direction (i.e., the axial direction of the system). The electromagnetic coils 11 are arranged in two sets; one set of 4 coils working in the X direction and the other set working in the Y direction. Each set includes two groups of coils. Each group has two coils arranged on the two sides of the stator body 1 and the flux plates 8 between them.

[0028] In FIG. 3, the floating ring 3 is shown displaced a small distance off its central position to the right, or in +X direction. The dotted lines in FIG. 3 represent the magnetic field intensity generated by coils C1, C2 excited in one direction and C3, C4 excited in the other direction. The arrows on that line show the direction of the field. On the other hand, the permanent magnets 2, which are identified as PM1 and PM2 in Fig. 3 generate two field intensity paths shown as solid lines with the arrows indicating the direction of the field lines. Examining the right hand side air gap, which has a smaller gap than the left side gap, the net magnetic field intensity is the difference between the field generated by the permanent magnet and the one generated by the coils. On the other side, the net magnetic field intensity is the sum of the two fields. In other words, the magnetic field intensity at the smaller air gap is reduced and the field intensity at the larger air gap is increased. Therefore, the net restoring force acting on the floating ring will act in the −X direction, i.e. to

restore the ring to its central position. The same principal works as well in the
Y direction. Therefore, by controlling the direction and value of the current
passing through the coils the ring can be centered.

[0029] The modification of the field intensity at the air gap may be referred to as field
modulation. The two sets of the electromagnetic coils 11 and their flux paths
are separated by using two return path plates 12 and 13 (FIGS. 1, 7A and 7B),
which preferably have about 5 millimeter (mm) air gap between them. This
arrangement eliminates, with a great success, the coupling between the X and
Y sets of coils 11.

[0030] For full validation of the present invention, a complete finite element model
was carried out, as shown in FIG. 11. The real model was enclosed within a
cylinder of air with a greater diameter than the model by 150% and greater in
height by 150%. This was needed to apply far field boundary conditions at the
surfaces of that cylinder. These boundary conditions were imposing a
tangential flux field at all the bounding surfaces of that cylinder. FIG. 11
shows the model meshed with air cylinder removed. The total number of
elements used to mesh this model is 370000. This huge number of elements is
used in order to obtain the most accurate results. On the other hand, the time
taken to perform one run is about 10 min. This type of analysis has the
advantage over the other methods (i.e. closed form solution...) in that there is
no simplification of the model geometry and it takes into consideration any
flux leakage.

[0031] The present invention was studied with the floating ring displaced from the
stator center incrementally .25 mm step in the X direction. Another study was
carried out with the floating ring displaced in the Z direction to get the holding
force in the Z direction that will support the ring weight and the axial force
resulting from the yarn tension. For the current configuration, the holding Z
force calculated (FIG. 13) is found to be about 5 [N]. This force is greater than
the sum of the floating ring weight and fiber tension in the Z direction by 5
times.

[0032] The materials used to manufacture the different components of the current
invention are: the stator body is made of Aluminum or any non-magnetic
material, the flux plates, floating ring and return flux plate are made of silicon
iron, the floating ring spacers, the stator spacers and the axial disk support are

made of plastic. The electric and magnetic properties of all these materials are available in any material handbook.

[0033] FIG. 12 shows the relation between the restoring force and the excitation current for 0.25, 0.5, 0.75 mm displacement of the floating ring from its central position. At the point (F0) of intersection with the current axis the sum of the forces acting on the ring is equal to zero. This does not mean that there is no force holding the ring at that point, but the force holding the ring in the X direction is equal to the force in the –X direction. So, by increasing the current with a small amount the ring will start to move in the direction where the air gap is larger. By this action the floating ring will restore its central position.

[0034] FIGS. 8, 9 and 10 show nonmagnetic spacers and the supporting ring. As described above, the two spacers are mounted on the floating ring and the other two are mounted on the stator body facing the other two spacers. The clearance between the facing spacers preferably is designed to be .75 mm in order to leave a 0.25 mm as an air gap between the floating ring and the stator. This 0.25 mm air gap is important in start up of the device. Of course, the present invention is not limited to any particular dimensions for the components described herein. However, for this particular design it has been determined that if this gap is less than this value the field modulation will not be able to pull the floating ring away from the stator. However, inversely, the magnetic force will increase in the direction of closing that gap more. This is quit clear from FIG. 12 at the 0.25 mm gap curve, where it can be seen that this curve is nearly tangent to zero force at 2.25 ampere (A), and if the current is increased the force starts again to increase in the opposite direction (i.e., trying to close the small gab further).

[0035] The supporting disk 7 (support the floating ring in the Z direction) will allow 1 mm for the floating ring 3 to be shifted downwards due to any unexpected disturbance. The permanent magnets 2 will still be capable of lifting the floating ring 3 up again. This action can be seen from FIG. 13 at 1 mm displacement where the resultant force in the Z direction is still about 5 Newton (N).

[0036] FIG. 14 shows the feedback control system of the present invention used to maintain the floating ring in its central position in accordance with the preferred embodiment. A conventional proportional-integral-derivative (PID)

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controller 30 preferably is used as a core of the control system. The control system 30 uses the two displacement sensors 20 (FIG. 2) to sense the floating ring position and feeds this information back (feedback signal) to the control unit 30. The control unit 30 calculates the difference between the feedback signal and the set point value and uses this difference through the PID algorithm to generate the required output signals. These signals are then amplified by amplifiers 31 and 32 and fed to respective different sets of the electromagnetic coils 11.

[0037] It should be noted that while the present invention has been described with reference to certain preferred embodiments, the present invention is not limited to these embodiment. The present invention is not limited to any particular dimensions for the components or with respect to the materials used to make the components. Also, the present invention is not limited to any particular arrangements for the permanent magnets and the electromagnetic coils. It should also be noted that although the present invention has been described with reference to ring-spinning, the present invention is applicable to any area of technology where it is necessary or desirable to suspend some type of device during operation, such as a ring or some type of bearing, for example. Other modifications may be made to the embodiments described herein without deviating from the scope of the present invention.